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SOME IDEAS CONCERNING BIOLOGICAL HEREDITY[1].

HITHERTO the theories of heredity most discussed by biologists have been those of Darwin and Weismann. To these might be added the hypotheses of Spencer and Galton.[2] Galton's hypothesis is a modification of Darwin's theory of Pangenesis, and is at the same time an approach to the theory of Weismann, for Galton antedates Weismann in maintaining the non-inheritance of acquired characters.

On re-examining the theories above mentioned, I was reminded of the hypothesis of Leibnitz, who, in his endeavor to explain the conception of original sin (which according to the Christian faith is transmitted from father to son), as a degenerate condition of the human soul which therefore has need of redemption to free itself from it, had recourse to the hypothesis that souls are contained in the seed from Adam down; that therefore there has been no new creation of souls from the beginning, because Adam contained all that were to be born and united with their future bodies by means of a pre-established harmony.

No philosopher after Leibnitz accepted this theory because it

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[1] Translated from the MS. of Prof. Giuseppe Sergi, of the University of Rome, Italy, by I. W. Howerth, Ph. D., of the University of Chicago.

[2] Spencer, *Principles of Biology*, Vol. I.; Darwin, *The Variation of Animals and Plants, under Domestication*, Chap. 27; Galton, "The Theory of Heredity," *Journal of Anthropological Institute*, Vol. V., 1876; Weismann, *Essais sur l'hérédité et la sélection*, Paris, 1892. Cf. Romanes, *An Examination of Weismannism*, Chicago, 1893; also his *Darwin and After Darwin*, Chicago, 1897.

does not seem rational. It appears to me, however, that the theories of heredity, especially the latest and the one most discussed, namely, that of Weismann, bear a strong resemblance to the Leibnitzian. For the germ plasm, like the stirps of Galton, is also supposed to have been contained in the primal ancestor, is equally immortal, like the soul of the spiritualist, and descends through the sexual cells, which are "the seed" of Leibnitz. The metaphysics is complete, and Galton himself is constrained to admit that it is necessary to theorise.[1] I shall not here enter into an extended discussion of the various theories of heredity proposed by Darwin and Weismann and by the opponents of the latter, because it would lead me beyond the limits of this paper. Since, however, from Darwin to Weismann there have arisen supporters and adversaries of the two principal hypotheses of evolution, the Darwinian and the Lamarckian, which are closely connected with heredity, I may say a word bearing upon the latter subject.

The gemmules of Darwin are derived from the cells which compose a multicellular organism, and are collected in the reproductive glands to form the two sexual elements from which a new organism is derived. It is not said that these gemmules, that is, the ovules and the spermatozoa, are immortal and in every organism substantially the same as in the parent organism; but it is said that they may be transmitted without having undergone any change to distant descendants where they may develop and produce the phenomenon of atavism.

So Darwin, while attempting to explain the appearance of atavistic forms, presented an hypothesis upon the heredity of specific forms. At the same time, he had to reconcile the persistence of such forms with the variations which are indispensable to explain the origin of species under the influence of natural selection. Darwin was, therefore, in a certain sense Lamarckian, because he admitted the influence of the environment upon the organism, and the effects of the use and disuse of organs.

The idea of the stability of these gemmules is still more ob-

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[1] "We are therefore forced to theorise." *Op. cit.*, p. 335.

vious in the theory of Galton, who called them "stirps," to which he attributed continuity, as does Weismann to germ-plasm. Galton declared emphatically that the stirps are only slightly subject to variation, and he opposed the validity of the theory of external action in heredity. That is to say, he admitted the nontransmissibility of acquired characters, except in a very few cases.

Weismann is the uncompromising advocate of the theory of the unaltered continuity of the germ-plasm, which, according to him, descends unvaried from generation to generation, and hence also of the nontransmissibility of acquired characters. Really I ought not to say that Weismann is a rigid supporter of his own doctrine, for he has modified it many times and has finally conceded that sometimes the hereditary transmission of acquired characters takes place. Now I wish to consider a certain phase of Weismannism, which is still in vogue in Italy and elsewhere, in order to show that it is theoretically untenable, and it is only theoretically that it is maintained, in so far as it regards the origin of variation in relation to natural selection. I shall endeavor to do this, because up to the present time no biologist has considered it in the same light.

Since the germ-plasm of Weismann is not subject to any influence, and only the somatic cells may undergo variation, it is natural that no individual variation may be transmitted by heredity. But the fact of variations exists, and it cannot be denied that there are transmissible or transmitted variations without forestalling ourselves from speaking of the origin of species, of selection, etc. Hence Weismann, constrained by the nature of the facts, admitted from the first that transmissible variations are only those which are produced in unicellular organisms, for he believed that the germ-plasm occupied the whole cellular substance which, therefore, could be directly modified by external influences. It might be said that Weismann was a Lamarckian only as regards unicellular organisms. But when a substantial distinction was made between the nucleus and the content of the cell, Weismann could no longer maintain this position, and the question of the possibility of hereditary variations even in unicellular organisms was raised.

There is only a single means, according to Weismann, whereby hereditary individual differences could take place, and that is sexual reproduction or amphigony. "It is well known that this process consists," he says, "in the coalescence of two distinct germ-cells, or perhaps only of their nuclei. These germ-cells contain the substance, the germ-plasm, and this again, owing to its specific molecular structure, is the bearer of the hereditary tendencies of the organism from which the germ-cell has been derived. In this amphigonic reproduction two groups of hereditary tendencies are as it were combined. I regard this combination as the cause of hereditary individual characters, and I believe that the production of such characters is the true significance of amphigonic reproduction. The object of this process is to create those individual differences which form the material out of which natural selection produces new species." [1]

Conceding to Weismann this proposition, we must ask him how it happens that in the two sexes, or better, in the two sexual cells, the variation of the germ-plasm is produced. For we must admit that the ovule and the sperm-cell contain like elements, being derived from organisms which had no original sexual differences, and that the variation in the ovule or the sperm cell did not constitute a variation in the germ-plasm which is found in the nucleus and is derived from an asexual organism. But Weismann does not answer this question. On the contrary, he supposes these conditions as an original fact.

Now, it seems clear to me that the origin of sex must not be sought in the germ cells, for these depend principally upon conditions external to the cells themselves, that is to say, upon particular conditions of the parent and of nutrition. Hence, if no variation in the germ-plasm is found at the beginning, none can ever be found, and the two cells, the ovule and the sperm cell, must have like germ-plasm, because, according to Weismann, they cannot undergo any alteration from the influence of the somatic cells. The mixing in sexual reproduction, then, cannot be the cause of heredi-

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[1] *Essais cit.*, p. 320.

tary individual variation no matter how great the number of successive generations.

Suppose, with Weismann, that the variations of the germ-plasm had originated in the unicellular organisms in the manner which he at first believed, that is, by the direct action of external causes. Still we could not admit that the multicellular organisms derived from them would have carried the variations acquired in the germ-plasm, and would have originated the innumerable variations which are found in the species. Such variations of unicellular organisms would have been limited, and would not have been able to produce all these effects, because as soon as unicellular organisms became multicellular they would have lost the condition of being able to undergo modifications through external influences, and would have been arrested at the first or most elementary variations already acquired in the unicellular condition. That is to say, there could not have been produced the innumerable species of animals and plants which now exist, and no natural selection could have been exercised.

Weismann, then, abandons even the possibility of variation in unicellular organisms. Since the germ-plasm is contained only in the nucleus, the way is closed, according to his own theory, to any variation even in these organisms. Even when unicellular organisms reproduce by amphigony they could only carry an unvarying and invariable plasma.

We may ask, then, How has it been possible that such a theory as that of Weismann could have attracted so much attention from the biologists of every country? I confess that it astonishes me to see it maintained by eminent zoölogists and naturalists of every sort, and so long discussed.[1]

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Turning now to the general conception of the hypotheses concerning heredity, I believe I can explain why it is that a substance called gemmule, stirp, idioplasm, and said to be immortal, unvaried and more or less invariable, is supposed to exist. It is doubtless

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[1] Cf. Romanes, *op. cit.*

the desire to find a basis for the fact of the conservation of forms in species and, in general, in the types of living beings of the two organic kingdoms, animal and vegetable. It is thought that without such a special substratum, separate, according to the theory of Weismann, from every other vital element, there could not be any stability of living forms. And since the variation in individuals is continuous and hence visible in every case, there has not been allowed to such variations the importance and the influence upon the reproduction of forms that they merit. Variations through external action resemble planetary perturbations, which are not capable of throwing a celestial body out of the orbit in which it is held invariably and eternally by virtue of the attraction of a greater body.

But this is a philosophic speculation, and represents the tendency of almost every thinker to seek for the occult and the mysterious. As I have already said, it seems to me that, from Darwin to Weismann, the hypotheses on heredity, multiplied in a few years, are analogous to that of Leibnitz concerning a pre-established harmony and the transmission of souls by means of reproduction, all of which souls being supposed to have been created at one time and no more afterwards, for no more were necessary. It is true that the gemmules and the germ-plasm are multiplied by division, but, according to Weismann, it is always the same substance, hence immortal. He attributes immortality to unicellular organisms.

The same speculation and the same hypothesis should be valuable even in another kingdom which has forms more definite and more stable than the animal or vegetable kingdom, namely, the mineral. Why not assume a special substratum for the production of mineral crystals as well as for the production of animal types?

Now, I ask, Why not seek a foundation for the stability of the reproduction of living forms which is simpler in its characters and more natural? Why recur to the hypothesis of an occult substance with occult qualities? Casual observation reveals in nature and in all its manifestations a tendency to stability, a perennial conservation in all its manifestations and energies, like the inertia of bodies

or the unaltered continuity of the laws of nature, which, while they may seem transitory, appear as constant phenomena.

To change this natural stability in a single manifestation it is necessary that superior forces act in determinate conditions. For instance, to separate the molecules cohering in a substance there must be a force which is superior to that of cohesion; to dissolve a crystal it is necessary that there be a condition which destroys that which has produced it and conserves it. In spite of the various energies which may disturb the movement of a celestial body it will always move in its orbit with great stability and constancy. So it may be affirmed that the succession of the phenomena of nature is constant in spite of the fact that there are disturbing causes. Chemical combinations, physical phenomena, transformation of energy, all speak of the continuity of natural manifestations.

We do not find it necessary, then, to invent a new alchemy treating of heredity in the two kingdoms of life. Man has had, and has yet, the tendency to occultism, it may be even with a scientific appearance, and to explain the phenomena of life he has invented now a *nisus formativus*, now a vital force, now a psychic, like the simple and immortal soul, now the spirit of the spiritualists, now the immutable and immortal germ-plasm.

The stability and the continuity which exist in all the phenomena of nature ought to reappear in the phenomena of life, which is also one of the phenomena of nature. The constant succession of living forms with the same characters is the most evident demonstration of this stability. In studying the micro-organisms, protophytes, and protozoa, one may observe the constancy of their forms and appearance. This constancy appears in the uninterrupted chain of heredity. If a living being could be born without the existence of another which precedes it, that is, without a parent, there would be no continuity and hence no stability. On the contrary there would be an interruption of the phenomena of law. Hence generation constitutes a continuity in succession, and heredity, a constancy in the reproduction of living forms.

The cell of the most minute and elementary organism is derived from a cell, and, as we know, by division. The formative

element is inclosed in the nucleus, and is that part which contains the energy and the center of vitality. From it there is an expansion of energy which is multiplied by generation, that is, by the cell's dividing itself and collecting in the protoplasmic substances surrounding it new nutritive elements. In such division and multiplication the individual cell cannot produce new individuals different from itself in form and function. In accordance with the stability of nature it produces homogenous individuals. In this phenomenon presented in its elementary form, it is not necessary to create an occult substance, a special plasm which is multiplied and generates new individuals while remaining unvaried and immortal. If anything immortal exists it is the form or the morphological characters of the living being. The living substance which has accumulated energy tends to expand, and is expanded by functioning or by dividing itself through successive generations.

Considering always the generation of a unicellular organism in the manner described, it is easy to understand that the living nuclear substance divided into two new and young individuals must be inferior in quantity and in energy to the mother substance or the generating individual if it is not increased by means of nutrition. But this is what happens, and then the new individual becomes like that from which it is generated, with the same amount of substance and equivalent energy. In this process, yet very simple, the form does not change, there is no condition to change it, and this happens in accordance with the fact noted above in every phenomenon of nature, namely, the conservative stability which constitutes the constancy and continuity of nature.

Whoever will observe closely the individuals of a unicellular type may find in them some variation, either in size or in length of cilia, if they are ciliated, etc. We may say that in their reproduction the type is perfectly conserved and the forms are constantly reproduced, but there is some deviation, which, however, does not in the least alter the type in its essential characters. This deviation constitutes the individual variation of the type.

What are the causes of these individual variations? How does it happen that the perennial constancy of forms may undergo varia-

tions in the succession of generations? Here new forces which are external, also natural, enter into action and exert an influence above that of these organisms, as happens with reference to other substances and forms of nature. We have said that a planet always describes its elliptical orbit around the star which attracts it, in spite of the perturbations which may be produced by other celestial bodies outside of its orbit. The attractive force of the sun is greater than that exerted upon the planet by other bodies. Hence it is held in its orbit. But these other bodies cause the planet to describe a curve irregular at certain points, and so the orbit, while preserving its elliptical form, may become sinuous.

If we consider that various forms of energy external to the living organism may act upon it, we may easily understand that some force may disturb its natural development and so produce a deviation from the parent type. Whatever be the circumstances, they may have their influence. Take, for instance, the ease or difficulty of finding food, its abundance or scarcity. In the minutest organisms this is perhaps one of the commonest conditions producing a variation in the individuals. But the environment in which they are born and are developed may undergo a change. In this manner we may conceive a series of influences which may be favorable or unfavorable to the conservation of the natural persistence of the organisms in their forms and corresponding functions. Thus there may be a condition which will produce a deviation from the type without destroying it, that is, may produce individual variations.

Without going beyond the generation of micro-organisms, in which the reproduction of forms seems simplest and more constant, and easier also to interpret, because we do not yet find in them a complexity of tissues and of organs, we may show, as a manifestation of the natural stability of living forms, some very important and at the same time surprising examples.

We do not know why it is that some protozoa have undergone such changes in reproduction as to acquire the mode of generation by spores. Under such circumstances the developing organism must pass through a series of changes and undergo considerable

transformations before it reaches the form of the type from which it originated. *Colpoda cucullus* (Fig. 1) shows admirably the various phases of development and the various metamorphoses through which the animal, which is an infusorian, passes before acquiring the definitive form. But it finally reaches it. Now, this demonstrates to us how, in spite of a series of deviations in the embryonal stage through which the *colpoda* passes, the typical form reappears constantly as a fact illustrating the persistence and stability of nature. Probably from the beginning external forces have acted with

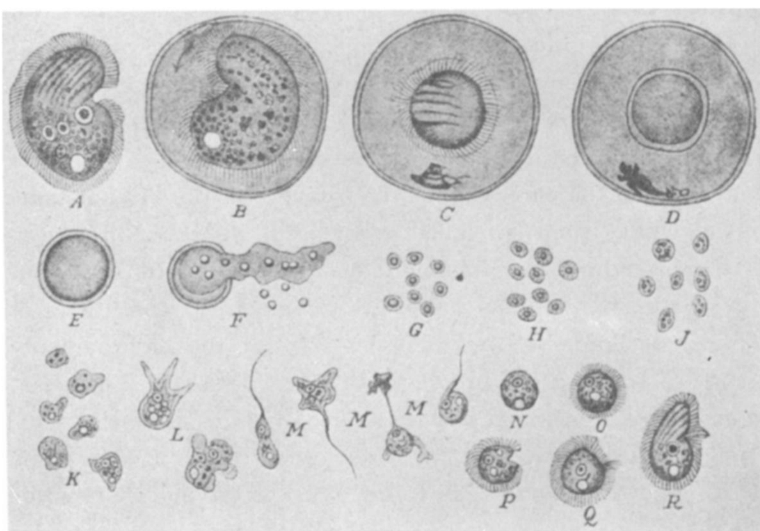

Fig. 1.
Evolution of *Colpoda cucullus*. (After Rumbler.)

great energy upon the micro-organism which assumed the encysted state to pass to generation by division. These causes may have coöperated with the reproductive energy to produce in the interior of the organism a great number of cells which, owing to the conditions in which they were born, could not have the same form as the cell born by division and whose form is complete, and identical to the mother cell. From this fact arises the necessity of freeing the embryonal cells or spores from their imprisonment. And these must undergo various phases of development before completing themselves in the adult form.

Whoever will observe the reproduction and the variations of *colpoda* will wonder why it must pass through so many changes. These changes are indicated in Fig. 1. *A* is the infusorian in its adult and typical form; in *B* it has reached the encysted state; in *C* and *D* there is a reduction of its volume, and the loss of its cilia. In *E* spores have been produced, and *F* represents the rupture of the envelope and the issue of the spores; the transformation of the spores *G* is visible successively in *H*, *J*, *K*, and *L*, in which the growing spore assumes the form of an amœba and then of a flagellata. Finally by degrees the typical form reappears in *R*. One might say that there has been a period of struggle between the natural stability of forms and the deviation determined by extraneous and external causes, but that stability, while undergoing temporary variations in the period of development, has finally conquered.

I have no need to create a germ-plasm with characters special and absolutely distinct from the other plasma which constitutes the body of the animal organism, to explain the reproduction of *colpoda*. Nor shall I be constrained to establish such a germ-plasm for the simple or primordial reproduction which takes place by division. The nuclear substance is sufficient to explain the phenomenon. In simple division there is the production of a new nucleus from the primitive nucleus, as an emanation from the latter, which is augmented by nutritious materials. In the formation of the spores in *colpoda* and other similar micro-organisms, I think we find the same phenomenon with an important variation arising from generative multiplication. That is to say, the nucleus undergoes a greater number of divisions, is protected as to the particles in which it is divided, by nutritive protoplasm and the tegument, in order that they may have time to develop themselves freely and under favorable conditions. Hence the same plasma which constitutes the most active part of the organism is that which is involved in the reproduction and multiplication of the organism itself. The reproduction of the type itself with its own morphological and functional characters, depends, as I have said, upon a natural stability or inertia which never varies unless a greater force acts upon the organism or upon the living substance of the various organisms.

Unless this is the case these organisms reproduce invariably the forms from which they are derived. It may be said, varying the signification, that there exists that fixity of species which the biologists before Darwin considered the effect of the original creation.

The transition from the production of spores to the production of sexual cells, ovule and sperm cell, resembles the transition from nuclear division to the production of spores. When an organism becomes complex and composed of many cells, and these are transformed into different tissues, it is no longer possible to observe cellular division as a means of reproduction, nor the production of spores which occupy and absorb the whole generating substance, as a means of reproductive multiplication. In composite organisms there must naturally and necessarily be a separation of the reproductive substance by another method. And this living reproductive substance must find a place to deposit itself and to await maturity and development.

Now, when we consider the conditions of more evolved animal life, we find two very special secretive organs, the spermatic glands of the male and the ovaries of the female. These two organs, which have also a special structure, are charged with collecting that which serves for the reproduction of the future organism and of forming it into characteristic cells, that is, the egg-cell and the sperm-cell. So a reproductive cell derived from a composite organism, for example, a vertebrate, a bird, a reptile, or a mammal will reproduce one of those types of animals from which it is directly derived. This always happens, and it is because of that natural stability and everlasting continuity which will neither change nor vary unless superior forces act momentarily or constantly to produce a variation and deviation from the type to which the organism belongs.

Now, in the individual evolution of an organism, let us suppose a mammal, the fertilised egg-cell is multiplied in the ordinary manner, that is to say, by division, as in micro-organisms, and in consequence of multiplication by segmentation it is divided and subdivided into parts which are to constitute the organs in the living adult. Among these organs are found also those which must serve

in sexual reproduction. I mean the ovaries and spermatic glands, with all those accessories which serve afterwards in reproduction. The two cells from which the individual is derived, or from which the tissues and organs are derived, do not already contain the living organism as an adult in microscopic proportions. There is no need to accept this old hypothesis. They contain the potentiality of developing themselves and reproducing individuals of the very same forms and with the very same functions as those organisms from which they originate, and this always by the continuous persistence of nature which does not vary without a sufficient cause.

I do not admit that in the sexual cells special elements are found which in the variation of the organism become muscles, bones, or nerves. I hold on the contrary that when the egg-cell is multiplied into numerous cells and has then formed the well-known layers, each of these layers evolves into those tissues and then into those organs which originally represented nerves, muscles, bones, etc. And here again we see the stability of nature, because we find that the parts which in the embryo are evolved into nerve tissue, for example, correspond to the very parts which in the variations of the organism constitute the external element in contact with natural agents, and hence served in the defence of the organism. A similar thing might be said of the parts which produce the organs of nutrition, etc. That is to say, stability is not only conserved in individual reproduction but also in the evolution and formation of species or general types, genera and species.

So, there is nothing pre-established, but on the contrary, all depends upon the constant stability of nature, and therefore nothing is variable except when acted upon by a force superior to that stability.

I have said that there are two organs charged with the production of sexual cells. These two organs begin to appear, like all the other organs, in the embryo. In the fœtus at maturity may be seen the glands which may serve in reproduction when the individual shall have arrived at puberty. Is it necessary that these organs, ovaries and spermatic glands, collect the germ-plasm of Weismann, the gemmules of Darwin or the stirps of Galton? I

think not. It is only necessary that they give form to special cells with special functions, functions which are reduced to those of developing and reproducing the entire individual with all its organs and special tissues; as the cells of the derm reproduce nerve-tissue, those of the mesoderm, the connective tissue, etc. The office of the fertilised egg-cell is more extensive, for it may produce, by segmentation, cells which are disposed in layers, external, middle, and internal. These layers then generate the tissues and the organs. So, while in reproduction by division and by spores, the reproductive element is the integral part of the generating individual, in sexual reproduction by means of sexual cells the reproductive element is a secretion of organs deputised to the special office of reproduction.

Sexual reproduction at first takes place by the employment of the whole living substance which composes an individual which has no sex; then in the employment of the substance of two distinct individuals, and finally in the employment of only a part of the substance of distinct individuals which have assumed a sexual character.

How the first takes place is shown in the reproduction by simple division of a unicellular organism (Fig. 2) and in reproduction by spores which are the transformation of the whole living substance into many other organisms by means of the spore element. But there may be an important variation in this latter phenomenon which may give rise to sexual reproduction, or at least may represent the transition to it.

Professor Delpino recently made a very important study of reproduction and of the origin of sex.[1] This investigation was conducted principally upon vegetables where it is easier to observe and to experiment than it is upon animals. He finds and describes six types of fecundation, two kinds extracellular and four intracellular. These types show with much evidence the origin and evolution of sexual fecundation. The first type is especially interesting in this connexion. It is that of the naked and undifferen-

[1] *Revista di Scienze Biologiche*. Anno. II., 4–5. Como.

tiated gonoplasts, called sexual zoospores, or zoogonides, or planogametes, by different authors. Zoogonides is the name proposed by Delpino himself, and I adopt it. These plants are algae, whose mode of generation is of the first type, and Delpino affirms that they belong to seven families which are the most ancient of the stock. Notice what happens: a cell (zoogonange) contains a plasma which is subdivided into many globules destined to be individualised into gonoplasts. By the rupture of the walls of the

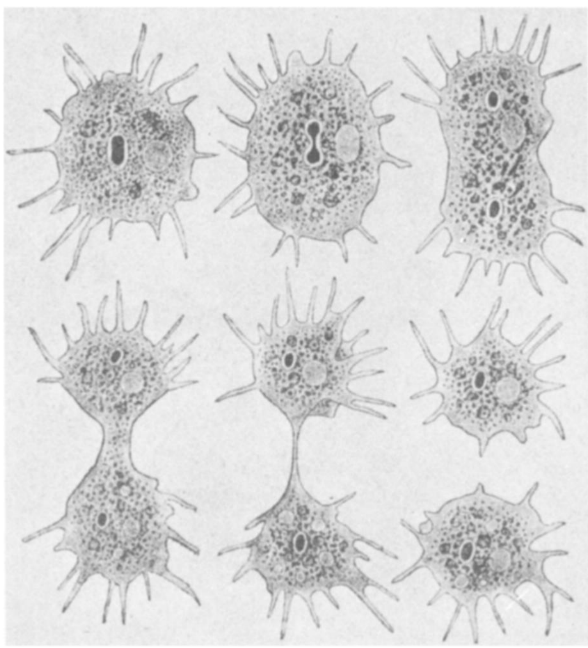

Fig. 2.

Amœba polypodia in six successive phases of scission. (After Schulze.)

zoogonangio, the globules issue forth and take on the pyriform figure with two cilia, by means of which they propel themselves rapidly through the water, and a beak. In their movement they encounter each other, unite in couples and finally fuse into one cell which becomes the new individual (Fig. 3). Delpino himself noticed that all the zoogonides do not find and unite themselves with others. Sòme are fixed, and like the spores, are developed into new individuals. That is, it may happen that their reproduction

may be agamic and sexual at the same time. There is here no illustration of real sexuality, but there is the origin of it, as appears from the second type mentioned by Delpino.

Without entering into the other very important problems concerning the origin of sex, so ably treated by Delpino, I wish to point out the fact that with this first type of fecundation, so admir

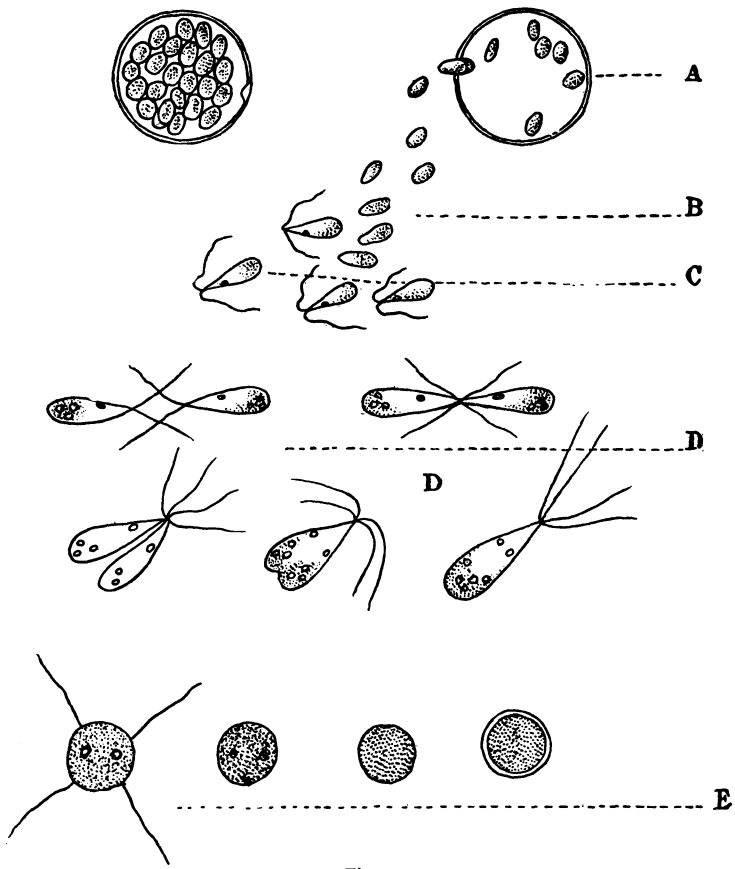

Fig. 3.

(*A*) Two cells (zoogonanges) with plasma divided into globules. (*B*) Globules which have assumed a pyriform figure with a beak and two vibratile cilia. (*C*) The corpuscles in movement naked gonoplasts). (*D*) The gonoplasts are united in couples and afterwards begin the process of fusion. (*E*) The successive stages (from left to right) up to the formation of the complete cell. (Delpino.)

ably described by him, we have the transition from reproduction by spores to sexual reproduction, and that in this transition is employed, as in the spores, the whole generative substance.

In a second stage of sexual reproduction we find the masculine and feminine elements distinct; but even in this case is equally employed the whole living parent substance, which is transformed into two sexual elements.

Finally there is a sexual reproduction in which only a small part of the parent substance is employed. This part is separated by a process which I have called secretion; two special organs, the ovaries and the spermatic glands, being constituted for the reproductive office. This third stage must naturally appear to be the most highly developed and the most perfect, because in this case the life of the parent is not sacrificed, as in the preceding cases. The parents survive and continue to produce new descendants without injury to their living substance. And it is the same with animals as with plants.

Hence, according to my conception of reproduction, whatever be the type or the stage of evolution of its scisions,—spores, or sexual union in the incipient or in the evolved form,—it is not necessary to admit the existence of a substance distinct from the living substance, which circulates and is transformed in every living individual and which has the predestined office of reproducing and of transmitting itself eternally without changing or varying, like the germ-plasm of Weismann. In the simpler living beings, which are agamic or amphygonic in the primordial forms, the living substance is all transformed into the reproductive elements with the death of the individual, and it is always and invariably the identical parent substance which is found in the individuals and in their descendants. So, also, in the higher and complete form of sexual reproduction, in which only a portion of the substance is employed, we may see that it must always be the same, and not another hidden and separate substance which assumes the reproductive office. The separation by means of sexual organs has taken place by a division of labor in the vital functions, especially from the time when the organisms began to have special tissues with their own functions, and when the utility of the individual's conservation became equal to that of the descendant.

If the heredity of forms is on account of the natural stability

of which I have spoken, which stability is like a force of resistance to all changes which may be produced by exterior influences, it follows that variations in organisms may take place only through the operation of forces which in special circumstances overcome the resistance exerted by nature against every change. This is the first condition for the production of variations in living organisms whether animals or plants. But this condition exists, because the living substance is in continuous and direct communication with external energies. In them and through them it lives and is preserved and even multiplies itself. Let us suppose that certain aquatic animals live in the sea at a profound depth and may also live at the surface. They are able to stand a definite aquatic pressure, let us say one hundred. Their organism is adapted to such a pressure, and when subjected to it, the parts are maintained in their normal condition. Their visceral cavities sustain no injury if they ascend to the surface or descend to the depth of a few meters beyond the average. Let us suppose, now, that by chance some of these animals which live at the surface are carried by some force to the depth of two thousand meters. Then, the aquatic pressure must be enormously increased, as, for example, to the extent of the difference between the weight of a column of water one hundred meters high and another of two thousand. Such animals could not resist so high a prèssure and would perish. But let us suppose that some one of them does survive. This one will be slowly modified to resist such high pressure. The external force in this case is superior to the natural stability which resists changes, and overcomes it; and consequently the changes are produced.

But the objection of the Weismann theory, and in part that of Galton, is made, not against the possibility of variations which may be produced in individuals, but against their heredity. The same example serves us here. If such changes should not take place in the animal which survived at the profound depth to enable it to support the great pressure, it would not continue to live but would perish without descendants. We have supposed that the changes take place. Such changes are variations useful to the continuance of life. Without them this could not happen. Such variations

are transmissible because a descendant of such an animal, if it should not inherit such variations, would perish and there would be no further descendants.

It is curious to notice that Weismann, in combating Nägeli's theory of a self-modifying idioplasm, insists that the environment may modify an organism in the direction of adaptation. He chooses the whale as an example. "The whale," he says, "is a placental mammal, which, probably in secondary times, arose from terrestrial mammalia by adaptation to aquatic life. Everything that is characteristic of these animals depends upon adaptation."[1] This being admitted, Weismann enters upon a description of the particular facts which distinguish whales as aquatic mammals from other terrestrial mammals, and finds that their organs are modified precisely by the new conditions of life in which they live. But the interpretation he makes of this phenomenon is, to say the least, strange. For he must invoke sexual reproduction to account for variations which are hereditary, if the germ-plasm cannot vary and the somatic variations are not hereditary. On the contrary, it seems to me that the adaptation implies that the somatic modifications are hereditary, supposing even that the somatic plasma is distinct or separate from the germ-plasm, as Weismann would wish to do. And it seems to me useless to invoke sexual reproduction to explain the fact, which fact does suppose the heredity of newly acquired characters.

My conception, then, concerning the heredity of acquired characters is that if such variations are useful to the species, animal or vegetable, they become hereditary, that is, permanent in the species, because they form an integral part of the organism which lives under conditions from which it cannot escape. If, however, the variations are superficial, that is, are not necessary to the species to enable it to continue to live and to leave descendants, then they may be hereditary but are not necessarily so. They may be transitory or individual. The higher examples, as of the fishes of the Plankton or the Necton, which pass into the fishes of

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[1] *Op. cit.*, p. 309 et seq.

the Benthos, and that of the whale of Weismann, show that the modifications or variations undergone in the new environment are necessary to the continuation of the life of the one and of the other. Hence they are not transitory, but are permanent and therefore hereditary.

I might yet say something in the way of explaining atavistic characters. I might construct an hypothesis as to how it happens that in the germ-cells, the ovule and the sperm-cell, the elements which reproduce the individuals from which these cells are derived may be found. But I have no intention of presenting a new theory of heredity, which would not be difficult to do, however, with a little use of the imagination. My purpose has been to show that the theories hitherto set forth are not only incapable of interpreting the facts of heredity but, what is more, they render them more complicated; that these theories are also a reappearance of occultism, because they seek for new plasma and admit occult virtues, as do the Vitalists and the Spiritualists; and that to interpret herredity as a general phenomenon it is enough to hold fast to the universal fact of the stability of nature, while variations imply the action of a force which modifies the organisms, which organisms, by the same natural persistence, must continue to live in the various conditions of their existence. I have sought to show by what means nature brings about descent and heredity in the different forms of reproduction, of which forms sexual reproduction is the highest and most evolved. In this form, therefore, individual existence is preserved because only a small portion of the living substance is employed in reproduction, and this substance is separated by a process common in vital functioning, namely, animal secretion. To my mind, therefore, the only plasma is that which composes the life-substance of all living beings, vegetal and animal, that is, the substance which Weismann would call somatic; and the germ plasm is in every case a derivation from it.

G. Sergi.

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